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Integration of Autonomous Cars with the Infrastructure of the City of St. Petersburg: Study of the Problems

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ABSTRACT

The article explores the problems of introducing autonomous cars (AC) into the transport infrastructure of St. Petersburg. The main problems among others comprise road technical condition and road equipment, security of data transmission, lack of technical capacity regarding data transfer rate, lack of regulation regarding technical issues. The study contains an assessment of the technical condition of roads as well as of presence of road markings necessary for positioning of AC on the road.

The suggested listing of the main parameters of road pavement condition substantiates the necessity to obtain relevant data and to equip the road system with appropriate sensors. The main areas important to ensure data transmission security during the design and construction of AC systems as described comprise security of collecting, transmitting, and processing data by AC systems, driver authentication, security of data transmission from road infrastructure. The study of the problem of data transfer rate incorporated a comparative analysis of the parameters of 4G technology, which is currently used by the infrastructure of telecom operators, and 5G technology, followed by the brief analysis of the barriers to adoption of 5G technology in Russia. The investigation of the existing regulatory and technical framework governing the operation of AC on public roads has identified a few key issues that are currently not governed by legislative acts or regulations.

The consideration of the problem of responsibility of road users has given ground to suggest that the responsibility must be extended not only to the owners of AC, but also to other participants in the process (manufacturers of AC, sensors, and software; organisations responsible for maintenance of transport infrastructure, manufacturers of the elements and structures of transport infrastructure, etc.). The analysis of the issue of the security of data transfer also regarded data transfer to third parties.

The study also referred to the issues of adaptation of adjacent industries involved to the process of AC implementation, as well as to the ethical issues in the process of decision-making by AC software in a critical situation. The formulated recommendations on improving the transport infrastructure of the city of St. Petersburg are aimed at solving the problems identified in the article.

Keywords: transport infrastructure, innovation, unmanned vehicle, implementation, 5G technology.

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BACKGROUND

Technological progress dictates the need to develop and improve the urban transport system. The economy, social sphere and the integral development of a state directly depend on efficient organisation of transport systems. The research in the framework of development of autonomous cars (AC)[1] suggests a large-scale spread of this phenomenon in the daily life of a person in the foreseeable future.

In Russia the Transport Strategy till 2030 with the forecast for the period till 2035 provides for a few directions of digital transformation of the transport industry. Namely, within the area of digitalisation of vehicles it considers development of driverless road transportation that will be in turn developed following two main directions. These are adoption «of intercity road haulage along key highways and of cargo and passenger transportation in the largest urban agglomerations». Consequently, within the area of digitalisation of transport infrastructure, since «intelligent transport systems allow to raise the safety of transportation, optimise the routes, increase transit capacity of transport system,.. to plan comprehensive development of transport infrastructure, including the infrastructure of control of highly automated and autonomous transport», it is proposed to use ITS «at infrastructure facilities of all modes of transport in the following formats of interfacing with V2X technology: vehicle – infrastructure, vehicle – vehicle, vehicle – any elements and facilities important for the purpose of transportation». This direction will provide for «development of standards of interaction with the help of V2X technology regarding intelligent transport systems, ensuring development of the networks of data transfer, shaping incentives for adoption and implementation of the national network of intelligent transport systems»[2]. These provisions of the Transport Strategy confirm the relevance of the study on the problems of the adoption of autonomous vehicles in the megapolis of Saint-Petersburg and of the development of elements of intelligent transport systems.

RESEARCH OBJECTIVE AND METHODOLOGY

Objective, Object and Subject of the Research

The *objective* of the research is identification of the problems referring to integration of autonomous cars with the transport infrastructure of the city of St. Petersburg.

The object of research is transport infrastructure of the city of St. Petersburg. The subject of the research is the problem of integration of AC with the transport infrastructure of the city of St. Petersburg.

To study the problems of integration of AC with the transport infrastructure of St. Petersburg, it is necessary to perform the following tasks:

1. To determine a list of critically important areas affecting AC integration with the transport infrastructure of St. Petersburg and to analyse each of them.

2. When analysing the current technical condition of roads and streets in the city of St. Petersburg, it is necessary to study the current regulatory and technical framework governing the technical condition of roads, statistical data on the technical condition of roads in St. Petersburg now, to reveal trends in changes in the situation regarding road pavement condition. As a result of the analysis, it is necessary to identify the main problems, the solution of which will allow safe operation of AC on public roads.

3. When analysing the problems of data transmission security, it is necessary to study the basics of data transmission, the security of their transmission, as well as ways of interaction between AC and the environment, including with intelligent transport systems (ITS). As a result of the analysis, it is necessary to formulate the main provisions that would improve data transfer security.

4. When studying the technical possibilities regarding data transfer rate, it is necessary to study the principles of building communication networks, to study the basic principles of coverage of the city with cellular communications by telecom operators. It is also necessary to analyse the current situation

[1] Since there are few denominations of this type of cars, e. g., self-driving car, autonomous car, autonomous vehicle, driverless car, robotic car (robo-car) and the authors have not intended to differentiate the topic of their interaction with the road infrastructure regarding exact type of autonomous cars, level of the autonomy (see, e. g., SAE classification) and interface used (e. g., connected car), except for particular cases of quoted papers, the most generic term of autonomous car (AC) is mostly used in the article. – Ed. note for English version.

[2] Transport Strategy of the Russian Federation till 2030 with the forecast for the period till 2035. Approved bby the decree of the Government of the Russian Federation dated 27.11.2021 No 3363-p. [Electronic resource]: http://static.government.ru/media/files/7enYF2uL5kFZlOOpQhLl0nUT91RjCbeR.pdf. Last accessed 13.04.2022.

Table 1

Data on the length of roads requiring repair [compiled by the authors based on data[4]]

Year	Total length, km	Technical condition meeting regulatory requirements, km	Require repair, km	Share of roads, requiring repair, %
2011	3096,9	2273,1	823,8	26,6
2012	3096,9	2359,8	737,1	23,8
2013	3276,9	2228,3	1048,6	32,0
2014	3290,5	2171,7	1118,8	34,0
2015	3337,5	2102,6	1234,9	37,0
2016	3414,6	2253,6	1161,0	34,0
2017	3433,6	2196,9	1236,7	36,0
2018	3461,8	2184,4	1277,4	36,9
2019	3472,2	2225,7	1246,5	35,9

with the provision of telecom operators with the existing number of base stations regarding their sufficiency for deployment of 5G technology in the city. It is necessary to study the issue of allocating frequencies in the Russian Federation for 5G technology.

5. When analysing the current legislative framework, it is necessary to study the current laws and draft laws regarding AC adoption and operation in the urban environment, and, based on the analysis of the current situation with regard to the legislative and regulatory framework, to identify and consider the main aspects that are not currently governed in the country by the regulations.

Problems of AC Introduction

The following problems are identified as the main ones for integration of AC with the transport infrastructure of the city of St. Petersburg [1]:

1. Technical condition and equipment of roads.

2. Data transmission security.

3. Lack of technical capacity regarding data transfer rate.

4. Lack of regulatory and technical framework.

RESULTS

To find solutions to eliminate the problems enlisted above, let us analyse the current situation.

1. Technical Condition and Equipment of Roads

1.1 Road pavement quality

First, for safe operation of AC, it is necessary to solve the problem of road pavement quality, bringing its condition to the standard one provided for in regulatory documents[3].

Table 1 presents data retrieved from the official website of the administration of St. Petersburg[4].

From the share of roads requiring repair in the total length of the road surface over the years, it can be concluded that the dynamics of the quantity of roads in St. Petersburg requiring repair and counted in kilometres practically does not change. In this regard, a radically new approach is needed to address the issue of repairing the road pavement in St. Petersburg to reduce to zero the quantity of road pavement requiring repair.

1.2 Availability of road markings

In addition to the direct repair of the road pavement, it is necessary to have and constantly keep road markings in good condition, since they serve the as the reference point for moving AC. The marking must be applied with a special reflective paint so that it can be read by AC sensors in any weather conditions at any time of the year. The operation of AC is possible on roads of all classes (considering the possibility of marking the roadway), however, when integrating AC with the infrastructure of the city, it is advisable to use initially roads of 1 and 2 classes[5]. This will reduce the risk of accidents involving

[3] GOST R [*Russian State Standard*] 50597-2017 Automobile roads and streets. The requirements for the maintenance quality satisfying the traffic safety. Methods of testing

[4] Official website of the administration of St. Petersburg. Committee for City Improvement of St. Petersburg. [Electronic resource]: https://www.gov.spb.ru/gov/otrasl/blago/uborka-dorog-i-trotuarov/. Last accessed 13.04.2022.

[5] GOST R 52398-2005. Classification of roads. Main parameters and requirements. [Electronic resource]: https://docs.cntd.ru/document/1200042582/. Last accessed 13.03.2022.

other road users and will also provide an opportunity to identify possible difficulties referring to the use of AC on other categories of roads, where there is more interaction with other road users.

Currently, the problem of cleaning roads in the winter is acute in the city of St. Petersburg. In case of poor-quality road cleaning the reading of road markings by AC will be impossible.

1.3 Road Technical Equipment

In addition to solving the existing problems with the technical condition of pavement, it is necessary to equip the roads along their entire length with sensors for reading by AC computer of the data on the road conditions [2], comprising information on:

• Irregularities on the road.

• Ice conditions during cold periods.

• Presence of moisture on the road (puddles, mud, snow: for calculation by AC control system of the speed limit and braking distance, etc.).

• Asphalt pavement temperature since at elevated temperatures in summer, asphalt becomes softer and more viscous during the contact with car's wheels.

A significant reorganisation is required to equip intersections with sensors, cameras, and traffic lights capable of transmitting information both to the traffic control post and directly to AC computer to organise movement within the traffic flow [3]. It is necessary to provide for transmission of data not only from the nearest intersection, but also from other intersections located on the AC route. This will allow choosing the most optimal route, since a traffic jam at the fourth crossroad from the current spot can affect the previously selected route.

2. Data Transmission Security.

The introduction and operation of AC involves generation of a large amount of information, such as data on location of objects, personal data of AC user, information about operation of infrastructure facilities, data for accessing both infrastructure facilities and directly AC, and much more [4]. To ensure cybersecurity of AC and of the entire infrastructure, the following important issues have been identified that must be considered when designing and creating systems [5]:

• Security of data collection, transmission, and processing by AC systems: security of data used in real time within the AC system (sensors, control units, etc.). In case of incorrectly configured security settings, attackers may be able to access data on the state of AC nodes at the time they are read by the AC system from sensors, processed, and when transferred to the general ITS system.

• Driver authentication: when using the services, the user needs not only to provide personal data, but also to pass their verification.

• Security of transmission of data by road infrastructure refers to programs used in collection and processing of data from various AC and ITS elements, as well as information or commands of ITS related to control and transmitted to AC systems. The actions of intruders who might have obtained access to such data can lead to making incorrect decisions by both ITS and AC.

3. Lack of Technical Capacity Regarding Data Transfer Rate

Current technologies of development of communication networks do not allow implementation of AC within the city since they do not meet the needs of AC when operating in an urban environment [6]. It refers to organisation of the process of operating a large number of AC as of a single element of the transport infrastructure of the city of St. Petersburg.

The current 4G technology does not satisfy the need for data transfer rate, latency, the number of connected users per square kilometre. A qualitatively new technology of communication networks is 5G technology. It will also not be able to fully satisfy the need to ensure sufficient communication quality for implementation of AC in full, but when providing coverage of the city with a network with 5G technology, it will make it possible to take the first steps to integrate AC with the urban transport infrastructure.

The main advantages of 5G technology (estimated data) compared to 4G are [7]:

• Peak rate of 5G technology is 20 times faster than 4G and is about 20 Gbps. Data exchange, as well as transfer of relevant information, is many times faster.

• Data transmission with 5G technology occurs with a delay of 1 millisecond, which is more than eight times less than that of 4G technology.

• The number of simultaneously connected users is an important criterion in densely populated cities with a high intensity of network use. 5G technology can simultaneously serve

1 million users per square kilometre, that is several orders of magnitude higher than current 4G technology.

In world practices, the n78 frequency range (3300–3800 MHz) is considered optimal for 5G technology [8]. Equipment of major manufacturers is produced just for this frequency range. In Russia, implementation of 5G technology was at a certain stage suspended due to problems with allocation of frequencies [9]. The State Commission on Radio Frequencies (SCRF) proposed the use of the n79 range (4400–5000 MHz). For telecom operators, the implementation of this solution causes a lot of problems [10], such as:

• The main producers, whose equipment is used for organising cellular communications by four leading national operators, do not manufacture the equipment intended exactly for this frequency range.

• The end consumers are not able to use 5G technology due to the rather limited number of smartphones that support the n79 frequency range. The manufacturers whose production is most distributed do not have 5G smartphones operating in the n78 range.

• Introduction of 5G technology in the n79 frequency range will entail an increase in the number of base stations (on average, by twice).

• The truncated bandwidth of the proposed n79 frequency range will not allow full implementation of the technology, since its bandwidth is half that of the n78 range.

Besides the 4400–5000 MHz range, telecom operators were offered frequencies in the 24250–29500 MHz range. This frequency range, in addition to the problems indicated above in the context of 4400–5000 MHz range, provoke difficulties with the very physics of the process. In the 24250–29500 MHz range and above, the signal is so sensitive to obstacles (walls of buildings, heavy rain, trees, etc.) that its full use is possible only in the absence of physical interference (buildings, dense canopy of trees and other obstacles). Within the urban built-up area of St. Petersburg, the telecom operators miss the main thing which is the economic benefits of the project. This is due to the fact that the number of base stations required to provide the coverage area increases many times over in relation to their current number, and the payback of the project is postponed for an unacceptably long period.

As part of the search for solutions, the Federal Antimonopoly Service (FAS) in May 2021 entered into agreements on joint activities to build 5G networks with three telecom operators among the four leading national telecom companies. PJSC MegaFon, PJSC Rostelecom and PJSC VimpelCom established a joint venture LLC New Digital Solutions [11]. At the end of autumn 2021, the SCRF decided to allocate the frequency range 4400–4990 MHz to LLC New Digital Solutions for testing 5G technology for a period of two years.

4. Lack of Regulatory and Technical Framework

The analysis of the current legislation[6, 7, 8] shows that there is no direct ban on the use of automated driving. At the same time, none of the documents stipulates the possibility of a complete transfer of driver functions to automatic control systems. From this it follows that initially it is necessary to make adjustments and additions to the main documents, clearly distinguishing and defining all cases of possible movement of the vehicle, both with direct control by the driver, and in the case of full control of the vehicle by automatic control systems.

Since December 1, 2018, the Decree of the Government of the Russian Federation dated November 26, 2018 No. 1415 «On conducting an experiment on trial operation of highly automated vehicles on public roads»[9] has been in force on the territory of Russia. It refers to regulation of experimental operation of AC on public roads with the mandatory presence of a driver in the car. This experiment is carried out in the regions listed in the document.

In parallel with the above decree, without waiting for its completion, on June 8, 2021, the Ministry of Transport of the Russian Federation submitted a draft Federal Law

[6] Federal Law dated November 8, 2007, No. 259-FZ «Charter of road transport and urban ground electric transport» (as amended and enlarged). [Electronic resource]: https://base.garant.ru/12157005/. Last accessed 13.04.2022.

[7] Federal Law dated December 10, 1995, No. 196-FZ «On road traffic safety» (as amended and enlarged). [Electronic resource]: https://base.garant.ru/10105643/. Last accessed 13.04.2022.

[8] Road traffic safety rules of the Russian Federation. Decree of the Council of Ministers – Government of the Russian Federation dated October 23, 1993, No. 1090 «On road traffic safety rules». [Electronic resource]: https://base.garant.ru/1305770/. Last accessed 13.04.2022.

[9] Decree of the Government of the Russian Federation of November 26, 2018, No. 1415 «On conducting an experiment on trial operation of highly automated vehicles on public roads». [Electronic resource]: https://base.garant.ru/72113462/. Last accessed 13.04.2022.

«On highly automated vehicles and on amendments to certain legislative acts of the Russian Federation».

This draft law considered the rules for the operation of AC on public roads on an ongoing basis. It gave the necessary definitions related to an automated vehicle, methods of its control, responsible persons involved in the process of its manufacture, driving and control, and defined a special device intended to record actions by an automated vehicle. The responsibilities of an owner, an operator and a manufacturer of an automated vehicle were also stipulated.

Today, this draft is subject to preliminary discussions and, taking into account the data obtained as a result of the experimental operation of AC, carried out in the framework of Decree of the Government of the Russian Federation of November 26, 2018, No. 1415, it will undergo amendments.

The draft is expected to come into force on March 1, 2025. This is because the period of validity of Decree of the Government of the Russian Federation of November 26, 2018, No. 1415 «On conducting an experiment on trial operation of highly automated vehicles on public roads» ends on March 1, 2022.

Thus, having studied the existing regulatory and legal framework currently in force in the Russian Federation, it was concluded that it is not sufficiently developed for full integration of AC with the transport infrastructure of the city. Below, there are a few main areas that need to be developed and stipulated in the legislative and regulatory framework.

Road safety

It is required to legislate on the responsibility of road users. To date, all the blame for a road traffic accident (RTA) falls on the owner of the AC. It is necessary, using the experience of foreign countries [12], to legally fix the possibility of exculpation of the AC owner if he can prove that his actions were not the cause of the accident. The examples are cases when accidents occurred due to the fault of the party responsible for the transport infrastructure, the AC software developer, a malfunction of AC sensors, etc. [13].

Regarding safety of AC operation, it is also necessary to legally regulate how certification of cars will be carried out, which is necessary for admission to the market of the country, as well as who and how will carry out periodic diagnostics of AC, its components and software.

Data transfer security

Normal operation of AC implies the use and transmission of a large amount of data. In terms of the technical component of equipment for processing a large flow of information, it is necessary to introduce regulatory standards for collection, processing, storage, and transmission of data [14]. Government agencies need to develop and implement data protection requirements at all stages of working with them: at the time of collection, processing, transmission, and their subsequent storage. Besides criminal liability, it is necessary to legally stipulate the possibility of processing and storing data obtained during AC operation, as well as the possibility to transfer information to third parties, such as law enforcement agencies.

Adaptation of the industries accompanying the AC implementation process

In addition to issues related directly to development, implementation and operation of AC, state institutions need to update and make amendments to the acts that govern other industries that are involved in this process. First, it is necessary to consider the issue of certifying the equipping of ITS with the necessary components, such as sensors, cameras, radars, equipment for data transmission and processing, as well as their storage. It is necessary to develop and to certify special signals, signs and indicators that will need to be added to the road infrastructure for normal functioning of AC.

Taking into account that a person as a driver in a normal situation during operation of AC will be excluded, and the software will be responsible for driving of AC, serious changes will affect the insurance industry. Because of a high probability that there will be a decrease in the risk of accidents due to the human factor, a fundamental change in the regulations on occurrence of insured events will be required. It will be necessary to adjust the methodology for calculating the cost of insurance, considering other factors affecting the risk of insured events.

Ethical issues in decision making

Besides all the above, it is necessary to determine and legally regulate the priority in decision-making by artificial intelligence in a critical situation [15]. It is necessary to approve an artificial intelligence decision-making algorithm that would be used when programming the AC would meet the requirements for

certification and subsequent admission of software to the country's market for further operation of AC. It is necessary to clearly indicate the priority of road users (driver, passenger of AC, passengers and drivers of other vehicles and AC, pedestrians, animals, material damage caused to someone's property, etc.).

5. Recommendations on the Revealed Problems

To solve the problems discussed in the article that impede AC integration with the transport infrastructure of the city of St. Petersburg, the following recommendations are formulated:

1. Ensuring the technical condition and equipping of roads in terms of quality of the road pavement, markings and technical equipment designed to obtain data on the state of the road pavement necessary for safe operation of AC.

2. Ensuring the security of operations with the data necessary for operation of AC on public roads.

3. Equipping the transport infrastructure of the city of St. Petersburg with 5G technology to ensure the data transfer rate necessary for AC operation.

4. Allocation of a frequency range for data transmission with the help of 5G technology that better meets the technical requirements.

5. Development of a regulatory and technical framework regulating the process of implementation and operation of AC within the transport infrastructure of the city of St. Petersburg from the point of view of traffic safety, data transmission, ethical aspect, as well as adaptation of related industries that ensure the normal functioning of AC within the transport infrastructure of the city.

CONCLUSIONS

The article has analysed the main problems that hinder the integration of AC with the transport infrastructure of the city of St. Petersburg, studied the problems of the technical condition of urban roads, and state of markings on the road pavement, considered the issue of equipping the roads of the city with equipment designed to obtain the parameters of the road pavement condition, which will be used by the AC systems for safe driving on public roads.

Considering the problems of data transmission security has allowed to identify the main areas that need to be taken into account when designing and creating AC systems, that comprise security of collecting, transmitting and processing data by AC systems, driver authentication, security in transmission of data by road infrastructure.

The study of the problem of data transfer rate resulted in comparison of the parameters of 4G and 5G technologies. From this comparison, it can be concluded that implementation of 5G technology will make it possible to take the first steps in organising the process of operating a large number of AC as of a single element of the transport infrastructure of the city of St. Petersburg.

The analysis of the current regulatory and technical framework and acts has permitted to formulate the main issues that are missing in the legislative and regulatory framework. The study of the problem of responsibility of road users has shown that the liability must be extended not only

to the owner of AC, but also to other participants in the process. The problem of the security of data transmission has been studied as well as of the transfer of data to third parties. The issue of adaptation of the industries involved in the process of AC implementation, as well as ethical issues in decision-making by AC software in a critical situation, have been considered, allowing to formulate the recommendations on the identified problems.

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